READ/WRITE TRANSDUCER FOR HARD DISK DRIVES WITH OPTICAL POSITION MEASURING SYSTEM, AND MANUFACTURING PROCESS THEREOF

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a read/write transducer for hard disk drives with dual actuation stage and to the manufacturing process thereof.

Description of the Related Art

As is known, hard disk drives are the media most widely used for storing data in personal computers; consequently they are produced in very large volumes and the maximum data storage density increases year by year.

The structure of a known hard disk drive is shown in Figures 1-3.

The hard disk drive, designated as a whole by 1, comprises a group of hard disks 2 rotating jointly with and parallel to each other around a rotation axis A and carried by a supporting structure 4 mounted on ball bearings (not shown) and actuated by a synchronous motor (not shown), generally known as "spindle motor."

The hard disk drive 1 further comprises a read/write device 6 for reading/writing the hard disks 2, comprising a supporting structure generally known as "E-block" 8 because of its E-like shape in side view (see Figure 2), which is angularly mobile around an oscillation axis B parallel to the rotation axis A of the hard disks 2 and is provided with a plurality of arms 10 orthogonal to the oscillation axis B and each carrying one or two suspensions 12, each formed by a steel lamina cantilevered with respect to the corresponding arm 10.

At the end not fixed to the corresponding arm 10, each suspension 12 carries a joint, generally known as "gimbal" or "flexure" 14, also made of steel, holding in turn a read/write transducer generally known as "slider" 16 and arranged, in operating condition, facing onto a surface of a corresponding hard disk 2, as shown in Figure 2.

As shown in greater detail in Figure 3, each gimbal 14 is generally formed from the corresponding suspension 12 and is composed, for example, of a rectangular plate 14a cut around on three and a half sides starting from the suspension 12 itself and having a portion 14b connected to the suspension 12 and allowing flexure of the plate 14a under the weight of the slider 16, which is therefore able to perform rolling and pitching movements in order to follow the surface of the corresponding hard disk 2.

Each slider 16 is formed by a supporting body 20 having a generally parallelepipedal shape with typical dimensions 1 x 1.2 x 0.3 mm, made of ceramic material, generally an alloy of aluminum, titanium and carbon (Al-Ti-C), and carrying, on its front face, a read/write head 22 (magneto/resistive and inductive) which constitutes the proper reading and writing device. Electrical bonding wires, not shown, extend from the read/write head 22 along the corresponding gimbal 14 and the corresponding suspension 12 to a signal processing device (also not shown) fixed to the mother board of the personal computer or other apparatus in which the hard disk drive is installed.

In the hard disk drives 1 currently on the market, each of the sliders 16 is glued directly onto the corresponding gimbal 14 and the movement of the read/write device 6 across the hard disks 2 is achieved with a motor, generally known as "voice coil motor" 24 (Figure 1), coupled to the E-block 8 to move it angularly around the oscillation axis B.

After having been subjected to all the surface finishing operations and having been fitted on the E-block 8, and before the final closing of the protective external casing in which the hard disk drive 1 is placed, control information is stored in each of the hard disks 2 in specific so-called pilot traces of specific so-called servo control sectors or servo sectors. During operation, this control information is then read by the sliders 16 and supplied to servo control devices (not shown) which process it to determine the position of the suspensions 12, and therefore of the sliders 16 integral with them, with respect to the corresponding hard disks 2, and to realize a closed loop control of the position of the sliders 16 so as to keep the reading heads 22 in an optimum reading position.

The market demand for a constant increase of the data storage density of hard disk drives 1 leads to an increasingly closer packing of the traces of the hard disks 2

and so the intrinsically poor precision of the voice coil motor 24 does not provide sufficient guarantees for the execution of the initial operation of writing the control information in the pilot traces of the servo sectors of the hard disks 2.

To overcome this inconvenience, an external precision actuation device is currently used, generally known as "spin-stand" 26 (schematically illustrated in Figure 1), which moves the E-block 8 with micrometric precision, and therefore also the sliders 16 on the corresponding hard disks 2, by means of its own output control shaft 28 coupled to one of the suspensions 12 and provided with an optical encoder (not shown).

Recently, however, to obtain more precise and finer control of the position of the slides 16 with respect to the corresponding hard disks 2, it has been proposed to use a moving device with dual actuation stage, in which a first rougher actuation stage including the voice coil motor 24 which moves the assembly formed by the E-block 8, the suspensions 12, the gimbals 14 and the sliders 16 across the hard disks 2 during the track coarse search, while a second finer actuation stage includes a plurality of integrated microactuators 30 (one of which is shown in Figure 3) each arranged between a corresponding slider 16 and a corresponding gimbal 14 and having the aim of carrying out a finer regulation of the position of the sliders 16 during the tracking.

An example of an embodiment of a rotary electrostatic microactuator 30 is described in the European patent application number 98830269.1, filed May 5, 1998 in the name of the applicant.

The introduction of a degree of freedom of movement between each slider 16 and the corresponding suspension 12 resulting from the introduction of a microactuator 30 means that, in order to be able to carry out the aforementioned initial operation of writing the control information in the pilot traces of the servo sectors of the hard disks 2 with the spin-stand 26, it is necessary to know, not only the position of the suspensions 12 with respect to the corresponding hard disks 2, but also the position of the sliders 16 with respect to the corresponding suspensions 12.

The determination of the position of a slider 16 with respect to the corresponding suspension 12 could, at least theoretically, be carried out indirectly by

determining the position of the microactuator 30, to which the slider 16 is restrained, with respect to the corresponding suspension 12, on the basis of the driving signals supplied to the microactuator 30, or by measuring the capacitive coupling existing between the rotor and the stator of the microactuator 30, since this coupling is correlated to the position of the microactuator 30.

In practice, however, this solution is difficult to put into practice, as the precision of determination of the position of the slider 16 with respect to the suspension 12 which may be obtained with this solution has proven to be insufficient for the execution of the initial operation of writing the control information in the pilot traces of the servo sectors in high data storage density applications in which the distances between the traces of the hard disks 2 are extremely reduced.

In fact, in the hard disk drives 1 with a dual actuation stage moving device of the type described above, the slider 16 is restrained to the corresponding microactuator 30 by gluing and generally the positioning of the slider 16 with respect to the microactuator 30 obtained with this type of connection presents a rather high degree of uncertainty, which has a significant influence on the precision of determination of the position of the slider 16 with respect to the suspension 12, making it insufficient for applications with high data storage density.

BRIEF SUMMARY OF THE INVENTION

An embodiment of the present invention provides a slider for a hard disk drive, a hard disk drive, a system for measuring the position of the slider, and a procedure for manufacturing said slider which allow the determination of the position of the slider with respect to the corresponding suspension with sufficient precision for any application with high data storage density.

According to an embodiment of the present invention, a read/write transducer for a hard disk drive is provided.

According to another embodiment of the present invention, a procedure for manufacturing a read/write transducer for a hard disk drive is further provided.

According to a further embodiment of the present invention, a hard disk drive is moreover provided.

Additionally, according to an embodiment of the present invention, a system for measuring the position of a read/write transducer for a hard disk drive is provided.

A method of operation of a device according to an embodiment of the invention is also provided.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

For a better understanding of the present invention, a preferred embodiment is now described, purely as an example without limitation, with reference to the enclosed drawings, in which:

Figure 1 is a top view of a known hard disk drive;

Figure 2 is an enlarged side view of some parts of the hard disk drive in Figure 1;

Figure 3 is an exploded view of a micrometric actuation stage forming part of the hard disk drive in Figure 1;

Figure 4 is a perspective view of a slider according to the present invention;

Figures 5-7 show steps of a process for manufacturing the slider in Figure 4;

Figures 8-10 show steps of a different process for manufacturing the slider in Figure 4;

Figure 11 shows a basic diagram for measuring the position of the slider in Figure 4;

Figure 12 schematically shows an optical apparatus for measuring the position of the slider in Figure 4; and

Figure 13 is a perspective view of a different embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Figure 4 shows a slider, designated as a whole by 32, according to the present invention. For clarity, parts indicated in Figures 4-13, which are similar to those in Figures 1-3, are indicated with the same reference numbers.

According to an embodiment of the present invention, during the slider manufacturing process, on one of the four side faces, here indicated with 34, of the supporting body, here indicated with 36, of the slider 32, a grating 38 is defined, which, as is known, is an optically detectable structure, periodic in reflection (transmission) and essentially formed by zones that reflect (transmit or refract) an incident electromagnetic radiation (light), alternating with zones that are non-reflective with respect to said incident electromagnetic radiation.

In particular, in its most general form a grating is formed by a pattern of lines or slits preferably parallel to one another, having the same width and spaced at the same interval, and, when impinged by a light beam, it produces fringe effects, in particular it generates a spatially periodic light distribution which appears as a so-called fringe pattern.

The structure and the optical properties of a grating are indeed widely known in the field of optical physics and are dealt with in many publications in the sectors, so they will not be analyzed any further hereinafter.

The grating 38 is formed during the slider manufacturing process in the way schematically illustrated in Figures 5-7, that is by initially depositing an oxide layer 40 on the side face 34 of the supporting body 36, then defining the oxide layer 40 through a chemical etch using a resist mask 42, later removed, reproducing the pattern of the grating 38, in particular reproducing the arrangement of the reflecting zones and of the non-reflective zones that one wishes to obtain, and finally metallizing (layer 44) the oxide layer 40 thus defined.

In particular, for the metallization of the oxide layer 40, for example, an alloy of aluminum and chrome (Al-Cr) may be used or the same alloy (aluminum, titanium and carbon Al-Ti-C) with which the supporting body 36 of the slider 32 is made.

The portions of the oxide layer 40 removed and not removed define a succession of crests and depressions alternating with one another. The metallized zones deposited at the removed portions of the oxide layer 40 define the non-reflective zones of the grating 38, while the metallized zones deposited at the non removed portions of the oxide layer 40 define the reflecting zones of the grating 38.

Alternatively, as schematically illustrated in Figures 8-10, the grating 38 could be realized without resorting to the deposition of the oxide layer 40, but rather by defining directly, with a chemical etch, the side face 34 of the supporting body 36 of the slider 32 using a mask reproducing the pattern of the grating 38, and then metallizing the supporting body 36 thus defined.

The determination of the position of the slider 32 with respect to the corresponding suspension 12 may therefore be carried out using the basic scheme illustrated in Figure 11, that is using a laser transmitter 46, essentially composed of a laser light source, able to emit, and to direct towards the grating 38, a laser beam, indicated with R1, and a laser receiver 48, essentially composed of a suitably calibrated photodiode, arranged in such a way as to intercept the laser beam, indicated with R2, reflected by the grating 38 and outputting a position signal on the basis of which it is possible to calculate simply the position of the slider 32 with respect to the corresponding suspension 12 in an absolute Cartesian reference system external to the hard disk drive 1.

The choice of the metal material for metallizing used in the definition of the grating 38 depends on the wave length of the laser light beam used for measurement.

Figure 12 shows a more detailed diagram of a measuring apparatus applicable to the spin-stand 26 for determining the position of the slider 32 with respect to the corresponding suspension 12 during the aforementioned initial operation of writing the control information in the pilot traces of the servo sectors of the hard disks 2.

As shown in Figure 12, the measuring apparatus, designated as a whole by 50, comprises a laser light transmitting/receiving device 52 essentially formed by the aforementioned laser transmitter 46 and laser receiver 48; an optical fiber 54 optically coupled, at a first end 54a, to the laser light transmitting/receiving device 52 and passed

through, in use, by the emitted laser beam R1 and by the reflected laser beam R2; a supporting structure 56, for example composed of an articulated arm, coupled to the output shaft 28 of the spin-stand 26 so as to be able to travel along a translation axis Z parallel to the oscillation axis B of the E-block 8 (orthogonal to the sheet) and onto which the second end 54b of the optical fiber 54 is fixed; an actuator 58, composed essentially of a electric step motor, coupled to the output shaft 28 of the spin-stand 26 and to the supporting structure 56 to move it along the translation axis Z; and a collimator 60 carried by the supporting structure 56 and optically coupled to the second end 54b of the optical fiber 54 with its own symmetry axis orthogonal to the grating 38 of the slider 32.

The determination of the position of the slider 32 with respect to the corresponding suspension 12 is carried out in the way described above with reference to Figure 10 and the position of the slider 32 with respect to the corresponding suspension 12 which may be calculated with the measuring apparatus 50 in Figure 11 is referred in a corresponding Cartesian reference system integral with the suspension 12.

In particular, it is stressed that the possibility of movement of the supporting structure 56 of the optical fiber 54 along the translation axis Z makes it possible to measure the position of all the sliders 32 (generally 6-8) of the hard disk drive 1 using the same laser light transmitting/receiving device 50.

From an examination of the characteristics of the slider 32 made according to the present invention the advantages that may be obtained with it are clear.

Firstly, the grating 38 may be formed on one of the side faces of the slider 32 in an extremely simple way during manufacturing of the slider 32 itself, as it requires only the definition of an oxide layer previously deposited on the side face of the slider 32 or the definition of the side face itself and its subsequent metallization.

Moreover, the definition of a grating 38 directly on one of the side faces of the slider 32 allows measurement of the position of the slider 32 with respect to the corresponding suspension 12 using optical apparatuses which, as is known, present extremely high precision suitable for the execution of initial operation of writing the control information in the pilot traces of the servo sectors of the hard disks 2 in high data

storage density applications in which the distances between the traces of the hard disks are extremely reduced.

Moreover, being defined directly on one of the side faces of the slider 32 during the manufacturing process, the grating 38 does not constitute an added weight for the slider 32 and therefore it does not interfere in any way either with determining the characteristics of the slider 32, of the corresponding suspension 12 and of the corresponding microactuator 30 (which consists essentially of determining the system oscillation modes and, depending on these, of the system mechanical properties, such as the torsional stiffness) nor with the closed loop control of the position of the read/write head 22, contrary to what would occur on the other hand if macroscopic optical systems were used, such as lenses, prisms, etc., glued onto the slider 32, and which, due to the extremely light weight of the slider 32 (1.6 mg) would represent additional masses comparable with the weight of the slider 32 itself and would therefore make it more difficult to establish both the closed loop control of the position of the read/write head 22, and the characteristics of the slider 32, of the corresponding suspension 12 and of the corresponding microactuator 30.

Lastly it is clear that modifications and variations may be made to the grating 28, to the slider 32 and to the manufacturing process thereof herein described and illustrated without departing from the scope of the present invention, as defined in the enclosed claims.

For example, the grating 38 could be produced on the supporting body 36 of the slider 32 in positions different from the one described and illustrated, in particular on different faces from the one indicated.

Moreover, a grating 38 according to the present invention could also be used advantageously in hard disk drives with a single actuation stage in which the slider is glued onto the gimbal. In fact, the grating may be used on this type of hard disk drive both during the writing of the control information in the servo sectors to carry out a further measurement of the position of the slider 32 with respect to the suspension in addition to the one already carried out by the optical encoder of the spin-stand, and during the normal

operation of the hard disk drive to determine with precision, at any time, the exact position of the slider 32 with respect to the corresponding suspension 12.

Moreover, when used in hard disk drives with a single actuation stage, the grating 38 could be provided on other parts of the hard disk drives apart from the slider 32, in particular it could be provided on the suspensions 12.

Figure 13 shows one of the possible positions of the grating 38 on a suspension 12. In particular, the suspension 12 shown in Figure 13 is of the type provided with so-called side rails, indicated with 62, and the grating 38 is positioned on the side rails 62.

Another possibility, not illustrated, could be that of providing the grating 38 on the gimbal 14; this positioning, however, is rather difficult to realize due to the small thickness of the gimbal 14 itself (a few tens of micron).

It should be noted that while this text makes reference to a read/write head, it is known in the industry that read only and write only heads may also be employed, and that, according to the principles of the invention, the exact nature of the transducer is not a limiting factor.

From the foregoing it will be appreciated that, although specific embodiments of the invention have been described herein for purposes of illustration, various modifications may be made without deviating from the spirit and scope of the invention. Accordingly, the invention is not limited except as by the appended claims.